Variation in Vegetative and Floral Characteristics of Potential Commercial Significance in Four Native Texas Coastal Species

Sean T. Carver, Michael A. Arnold, David H. Byrne, R. Daniel Lineberger, Andrew R. King
Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843-2133, USA

and

Anna R. Armitage
Department of Marine Biology, Texas A&M University, Galveston, TX 77551, USA

ABSTRACT

With increasing demand for high quality irrigation water and active regional coastal development, new plants need to be developed that thrive with the use of saline irrigation and provide an alternative to invasive exotic landscape plants. Regionally native coastal species offer a potential solution. Accessions of *Erigeron procumbens* (Houst. *ex* Mill.) G.L. Nesom, *Borrichia frutescens* (L.) DC., *Sesuvium portulacastrum* (L.) L., and *Oenothera drummondii* Hook. were collected along the Texas coast from Port Isabel to Port Arthur. Then taxa were screened for phenotypic variability in morphological traits that may benefit the landscape industry. There were differences among accessions for all four species and there were regional differences in flowering and height for *B. frutescens* and *O. drummondii*. Mean height for *O. drummondii* accessions ranged from 8 to 68 cm. Flower count varied among *O. drummundii* accessions, with those collected from the southern region tending to only flower in the fall. Flower size and color were not variable for *O. drummondii*, however foliage color was variable among accessions. Plant height for *B. frutescens* accessions ranged from 17 to 78 cm. Phenotypic variability appeared most promising in *O. drummondii* and *B. frutescens* for future breeding efforts. Regional trends were identified in many traits within each species. Published on-line www.phytologia.org *Phytologia 98(4): 250-276 (Oct 6, 2016)*. ISSN 030319430.

KEY WORDS: Native plants, phenotypic variability, *Oenothera drummondii*, *Borrichia frutescens*, *Erigeron procumbens*, *Sesuvium portulacastrum*

With the decreasing availability of high quality irrigation water in urban areas, new ornamental crops need to be developed for landscapes that will thrive with lower quality saline irrigation water. One source of irrigation water in arid climates is recycled treated effluent water. One concern with this source of irrigation is elevated salinity that can be as much two to three times the content of potable water (Khurram and Miyamoto, 2005; Wu et al., 2001). When introducing plants to the landscape or nursery trade it is important to determine the extent of variation present in native populations for ornamental traits. *Oenothera drummondii* Hook., *Sesuvium portulacastrum* (L.) L., *Borrichia frutescens* (L.) DC., and *Erigeron procumbens* (Houst. *ex* Mill.) G.L. Nesom were selected from Texas coastal regions based on their close proximity to the coast (Correll and Johnston, 1970; USDA Plants Database, 2009). This proximity to the coast would likely provide natural tolerance to salt exposure, especially in the form of sodium and chlorine ions because in these habitats plants are exposed to saline conditions (Taiz and Zeiger, 2006). Regional native plants were also selected because of growing trends toward use of natives in built landscapes for their adaptability to their endemic region and low potential to become invasive. Sensitive coastal ecosystems can be threatened by invasive exotics such as Brazilian pepper tree (*Schinus terebinthifolius* Raddi), melaleuca (*Melaleuca quinquenervia* (Cav.) S.F. Blake), and water hyacinth (*Eichhornia crassipes* (Mart.) Solms) (Ewe and Sternberg, 2002; Turner et al., 1998; Villamagna and Murphy, 2010). Use of native species could avoid this problem.

Not all native plants may be suitable for general use in built environments, particularly in coastal locations. Plants selected must be able to adapt to commercial container nursery production techniques, tolerate low quality irrigation water, tolerate salt exposure, and have some form of regional and/or genetic variation to provide a basis for the future improvement of cultivated selections.

Documenting the amount and kind of variation in desirable traits within a species is important for the success of a plant improvement program (Zobel and Talbert, 1984). Variation that is present due to geographic differences should be documented first, followed by variation that occurs from other sources (Zobel and Talbert, 1984). "Ecotypic variation is a distinct morphological or physiological form, or population, resulting from selection by a distinct ecological condition" and "is the whole basis of provenance studies" (Arnold, 2008). Provenance studies should provide the foundation for genetic improvement of plant species (Morganstern, 1996). It appears that most adaptability traits are additive in nature and gains in improvement programs can be made by selecting individuals that already possess traits permitting grow in suboptimal conditions (Zobel and Talbert, 1984).

Ecoptypic variation in leaf morphology and plant height has been documented in several species including *Helianthus annuus* L. (sunflower), *Carya illinoinensis* (Wangenh.) K. Koch (pecan), *Spartina patens* (Aiton) Muhl. (saltgrass) and *S. portulacastrum* (Hester et al., 1996; Lokhande et al., 2009; Nooryazdan et al., 2010; Wood et al. 1998).

The objectives of experiments described herein were to begin to characterize the variation in traits of ornamental interest in Texas' coastal populations of *O. drummondii*, *B. frutescens*, *E. procumbens*, and *S. portulacastrum* in a common field location and under container nursery conditions.

MATERIALS AND METHODS

Clonal material of *B. frutescens*, *E. procumbens*, *S. portulacastrum*, and *O. drummondii* was collected from locations along the Texas coast from South Padre Island, Texas to Port Arthur, Texas. Global positioning system (GPS) data and physical location data were recorded (see appendix). Stock plants were generated from the collected material and used to conduct this provenance study in College Station, Texas.

Tip cuttings, 4-6 cm long, were taken on 17 April 2010, from containerized stock plants maintained in a gravel bottom nursery in College Station, TX (30° 37' 24.24", -97° 22' 0.17"). Basal ends of cuttings were dipped in talc based indolebutyric acid at the concentration of 1 $g \cdot kg^{-1}$ (Hormodin® 1, OHP, Inc., Mainland, PA). Cuttings were placed in 36 cm x 51 cm x 10 cm deep flats (Kadon Corp., Dayton, OH) filled with coarse perlite (Sun Gro Horticulture Canada Ltd., Seba Beach, AB). Intermittent mist was applied at 16 min intervals for a 15 sec duration using reverse osmosis water from 1 h before sunrise to 1 h after sunset. On 13 May 2010, rooted cuttings were potted in 0.47 L black plastic pots (Dillen Products, Middlefield, OH) containing Metro-Mix 700 media (Sun Gro Horticulture Canada Ltd., Vancouver, BC.

Container responses: rooted cuttings generated as described above, from each accession collected, were potted into 2.3-L black plastic containers (C400, Nursery Supplies Inc., Kissimmee, FL) containing Metro-Mix 700 media (Sun Gro Horticulture Canada Ltd, Vancouver, BC with 6.53 $kg \cdot m^{-3}$ 15N-3.9P-9.9K controlled release fertilizer (3-4 month Osmocote® Plus, Scotts Co., Marysville, OH) on 3 June 2010. Plants were placed in an outdoor gravel bottom nursery with full sun exposure in a completely randomized design with three replicates of each genotype collected (n=3). Plants were irrigated as needed by hand using tap water with constant fertilizer injection (300 $mg \cdot L^{-1}$ of N, Peters Professional 20N-8.74P-16.6K, Scotts Co., Marysville, OH). On 10 July 2010 plant height, leaf lamina length, leaf width, internode length, stem diameter, and flower diameter were recorded for each as was done with other species in prior studies (Hester et al., 1996; Nooryazdan et al., 2010; Wood et al., 1998). Leaf and internode measurements were taken from three fully expanded leaves per plant. Flower data were taken from three open flowers per plant.

Landscape responses: rooted cuttings generated as described in the container nursery experiment were planted in field conditions at the Texas A&M University Horticulture Farm (30° 37' 34.0608", -96° 22' 14.2104") with five replicates of each genotype (n=5) on 1 m in row spacings and 4 m between row spacings on 2 June 2010. The soil was a sandy clay loam (66% sand, 8% silt, 26% clay) with a pH of 6.0. Plants were drip irrigated (T-Tape Model 505, Deere and Company, Moline, IL) as needed to maintain turgidity. Flower counts, growth index (height x width in the widest direction x width perpendicular to the widest direction), and an ornamental rating were taken at the end of the growing season (1 November 2010). End of the season plant height, leaf lamina length, leaf width, internode length, and flower diameter were recorded for each genotype (Hester et al., 1996; Nooryazdan et al., 2010; Wood et al., 1998). Leaf and internode measurements were taken on three fully expanded leaves on each plant. Flower width at the widest point was collected from three open flowers on each plant.

An ornamental rating of 1 to 5 was recorded by the same observer at harvest, with 1) representing a dead plant or plant near death (unacceptable for ornamental use), 2) plant with severe damage to the canopy but surviving, 3) plant with open holes in the canopy, erratic growth, and general lack of flowers, 4) canopy was full with uniform growth throughout, with or without flowers (acceptable ornamental landscape plant), and 5) canopy is full with uniform growth throughout with flowers covering at least 10 % of the canopy (acceptable ornamental landscape plant).

The accessions were separated into large regional groupings based on collection site along the Texas coast (Fig. 1.), then statistically analyzed using ANOVA in JMP (SAS Institute Inc., Cary, NC). Effects were considered significant at $P \leq 0.05$. Hierarchical cluster analysis with Wards distance was performed. All non-normal data were analyzed using permutations in the lmPerm package (Wheeler, 2010) in R (R Core Team, 2013), set to defaults.

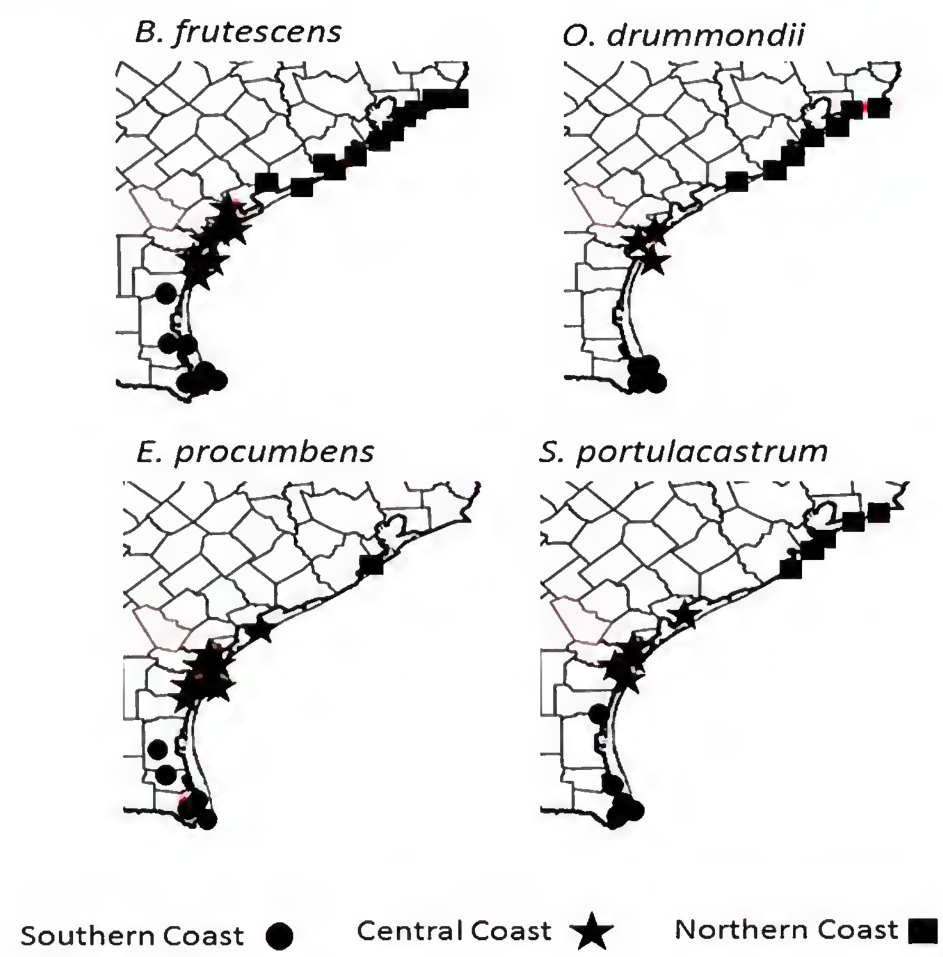

Fig. 1. Collection regions for accessions of *B. frutescens, O. drummondii, E. procumbens*, and *S. portulacastrum*.

RESULTS AND DISCUSSION

Oenothera drummondii

Differences occurred ($P \leq 0.05$) amongst accessions of *O. drummondii* (beach evening primrose) for height, height/width ratio, flower count at harvest, flower diameter, leaf length, leaf width, petiole length and the number of serrations present on each leaf (Tables 1 and 2a). When accessions were allocated to regional groups along the Texas Coast (South, Central, and Northern) based on original collection location there were differences among regional groups and accessions for height, height/width ratio, flower count, leaf length, leaf width, and petiole length. Internode length was only significant for environment (nursery versus field locations) but not for accession or collection region.

Height varied from 68 cm to 8 cm with a mean across all accessions of 25.2 cm and height:width ratio ranged from 0.67 to 0.05 with a mean of 0.30 (Table 3). Larger height:width ratios are characteristic of upright plants and lower ratios are indicative of a spreading habit. In general, accessions from the southern coast were taller in field conditions than plants from either the central or northern Texas coast (Table 2a). This would explain the negative correlation between height and latitude of original collection site (r = 0.56) and the negative correlation between height:width ratio and latitude of original collection site (r = 0.49) (Table 3). All accessions, except O10, were not as tall in the nursery environment as they were in the field environment. There was an interaction for environment by accession for height (Table 1). In the field environment, O10 had a mean height of 12.8 cm and in the nursery environment O10 had a mean height of 13.7 cm. All other accessions had reduced height in the nursery compared to the field environment.

Flower count was different ($P \leq 0.05$) among the individual accessions, dependent on the environment in which they were tested, yielding a significant accession by environment interaction (Table 1). The accessions from central and northern collection sites tended to have more flowers in both the nursery and field environments (Table 1). All groups did not flower as freely in the nursery environment as they did in the field conditions. Some accessions came into flower sooner such as O13 in the nursery environments and O16 in the field environment (Fig. 2). Early flowering accessions were not consistent between the two environments and some accessions came into heavier flower later during the experiment (Fig 2). This could be due to the longer natural photoperiod at time of harvest and a more constricted root zone when the plants were grown in containers and the smaller size of the container-grown plants. Plants were smaller across genotypes in containers. The mean growth indices (height x width at widest point x width perpendicular to widest point, a pseudo-volumetric estimate of canopy size) was 63,958 cm^3 in the nursery compared to 551,452 cm^3 in the field, nearly a nine fold difference in size. Several accessions from the southern collection region might be photoperiod sensitive (Tables 2a, b, and 5). Nursery grown plants were harvested in late summer (7 July 2010) and field grown plants were harvested at the end of the season (1 Nov 2010); if the accessions were sensitive to day length, then field grown plant were exposed to shorter days. There are many reports of members of the genus *Oenothera* L. being sensitive to day length, so the presence of day length sensitivity in some accessions would not be surprising (Clough et al., 2001; Gimenez et al., 2013; Kachi and Hirose, 1983).

Further studies need to be performed to determine whether it is indeed photoperiodicity or other factors such as plant size, temperature, or general reluctance to flower that dictate differences among accessions. Further testing is needed due to a lack of sampling dates (Fig. 2). Collections from the southern region had lower flower counts but, as far as ornamental value is concerned, better growth habits with fewer defoliated sections in the canopy as shown in Figure 3.

This is also analogous to results reported by Gratani et al. (2003), who found that *Quercus ilex* L. (holly oak) leaf morphology was related to provenance in varying mesic and xeric climates. This could explain the smaller leaves in the field on accessions from the southern coast. Average rainfall along the Texas coasts varies from 61 – 71 cm in the southern region, 91 – 101 cm in the central coast to 132 – 142 cm in the northern coast (Texas Water Development Board, 2014).

In general, all leaf measures increased in the nursery environment, most likely from more favorable cultural conditions in the form of ample water and nitrogen fertilizer. When accessions were grouped by collection region, accessions from the south had shorter leaves than plants from either the central or northern collection zones in the field. However, when grown in nursery conditions, plants from the southern region had larger leaves than plants from either the northern or central regions (Table 2a). This suggests leaf morphology is more plastic in accessions from the southern Texas coast and may provide some form of adaptability to harsher environments as has been reported for other taxa (Sultan, 1987; Wood et al., 1998; Gratani et al., 2003).

The number of leaf serrations is also reduced in the southern region accessions, with *O. drummondii* from the northern regions having more leaf serrations on average (Table 2a). In addition to reduced leaf serrations, accessions from the southern collection region tended to have blue foliage, (Chi Square $P = 0.0001$) whereas the other collection locations tended to have green foliage. Sixty-six percent of blue observations were collected from the southern location. The blue foliage color is brought on by the increased presence of pubescence on the leaves, another drought adaptation strategy employed by many plants (Sandquist and Ehleringer, 1998; Ehleringer and Mooney, 1978), and likely reflecting the reduced rainfall in the southern collection region.

Leaf length and plant height, and number of leaf serrations and plant height were both negatively correlated -0.45 and -0.54, respectively (Table 3). Wood et al. (1998) also found correlations among height and latitude and other leaf characteristics such as leaflet droop angle and leaflet tilt angle and latitude in pecan [*Carya illinoinensis* (Wangenh.) K. Koch]. Pecan tree height and latitude were negatively correlated with increasing height and decreasing latitude (Wood et al., 1998), very similar to what was found in *O. drummondii* in this study. Number of leaf serrations and height were also correlated to the longitude of the original collection site (Table 3). Flower count was weakly correlated to leaf width and length, but not to latitude of collection site (Table 3). This suggests that in each group there might be free-flowering and not free-flowering accessions.

Based on hierarchical cluster analysis using only morphologic measures, accessions clustered into two large groups (Fig. 4). This is different than the expected three clusters based on location of collection. Accessions collected from central and northern locations formed one large cluster and accessions from the southern collection locations formed a separate cluster. This is in line with Nooryazdan et al. (2010) who also found that sunflowers (*Helianthus annuus* L.) from similar climatic zones clustered together. One accession of *O. drummondii* collected from the central coast (O2) clustered in the southern group as did one accession (O1) from the southern region which clustered with the northern accessions. Neither accession O1 or O2 were from transition zones. These clustering patterns were also supported by least significant difference means separation performed on the means of the three regional groups for height, flower count and height:width ratio (Table 4). For these measures only plants from the southern region were significantly different from the other collection locations.

There is variation among accessions of *O. drummondii* when sampled from the southern, central, and northern coasts of Texas for height, propensity to flower, growth form, leaf length and width, as well as the number of serrations on the margin of the leaf. We did not find variation in flower diameter based on the region of collection but it was present amongst the accessions as a whole. There was no significant variation in internode length associated with region of collection or accession. There also was no significant variation found in flower color based on visual observation (data not presented) all were of a similar shade of yellow. Plants from the southern collection region tended to have blue foliage.

Table 1. Means of growth measures by accession and regional grouping along the Texas coast of *Oenothera drummondii* grown in field and nursery conditions.

	Height (cm)		Height/width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)		Flower Count (No./plant)		Flower Diameter (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
1	31.0 ± 5.8[T]	21.7 ± 5.2	0.27 ± 0.04	0.31 ± 0.07	8.7 ± 1.0[V]	34.3 ± 7.0	0.6 ± 0.4	0.0 ± 0.0	51.4 ± 1.4	-
2	42.8 ± 3.0	22.0 ± 2.3	0.31 ± 0.03	0.31 ± 0.03	13.7 ± 1.8	18.1 ± 3.0	17.6 ± 4.8	1.0 ± 1.0	62.3 ± 1.4	60.6 ± 2.8
3	47.6 ± 4.6	22.7 ± 3.5	0.30 ± 0.03	0.33 ± 0.10	11.6 ± 1.4	17.6 ± 2.7	4.8 ± 1.0	0.0 ± 0.0	55.1 ± 1.7	59.7 ± 2.7
4	52.75 ± 4.4	23.0 ± 2.6	0.33 ± 0.04	0.39 ± 0.06	14.3 ± 2.4	21.9 ± 2.9	11.8 ± 3.6	0.3 ± 0.3	59.4 ± 1.4	-
5	51.0 ± 17.0	24.7 ± 2.0	0.39 ± 0.09	0.40 ± 0.06	11.0 ± 1.0	17.2 ± 2.6	17.0 ± 16.0	0.0 ± 0.0	54.6 ± 1.5	-
6	49.6 ± 5.0	23.0 ± 2.6	0.36 ± 0.08	0.37 ± 0.02	11.6 ± 1.1	24.4 ± 1.5	0.0 ± 0.0	0.0 ± 0.0	47.9 ± 1.2	-
7	23.6 ± 4.0	14.0 ± 1.5	0.35 ± 0.08	0.24 ± 0.03	11.2 ± 0.9	19.6 ± 2.5	4.2 ± 0.8	0.7 ± 0.7	55.0 ± 2.4	59.8 ± 3.3
8	14.2 ± 2.3	13.3 ± 1.8	0.13 ± 0.03	0.20 ± 0.03	11.4 ± 1.3	24.2 ± 3.5	7.2 ± 2.9	1.7 ± 0.3	62.5 ± 1.7	58.3 ± 5.1
9	23.0 ± 4.1	14.7 ± 3.3	0.20 ± 0.04	0.18 ± 0.04	13.7 ± 1.4	24.1 ± 1.9	11.4 ± 3.9	3.3 ± 1.3	65.0 ± 2.4	51.4 ± 6.8
10	12.8 ± 1.5	13.7 ± 2.4	0.12 ± 0.02	0.18 ± 0.03	10.5 ± 0.6	22.7 ± 2.9	9.4 ± 2.7	3.7 ± 0.6	51.8 ± 1.8	56.4 ± 2.3
11	20.0 ± 4.5	15.0 ± 2.0	0.15 ± 0.04	0.20 ± 0.03	10.5 ± 0.7	19.8 ± 1.8	34.0 ± 11.7	3.3 ± 1.3	53.5 ± 1.2	57.1 ± 0.8
12	25.6 ± 3.7	22.0 ± 2.5	0.19 ± 0.02	0.35 ± 0.04	12.7 ± 1.1	34.0 ± 4.8	33.4 ± 9.1	0.3 ± 0.3	60.3 ± 2.0	63.6 ± 3.6
13	17.8 ± 2.8	15.0 ± 1.5	0.29 ± 0.03	0.27 ± 0.01	8.0 ± 0.6	14.6 ± 1.1	4.0 ± 1.4	2.0 ± 1.0	55.0 ± 1.8	53.7 ± 3.3
14	28.2 ± 2.6	13.7 ± 1.2	0.19 ± 0.02	0.18 ± 0.01	10.6 ± 1.3	24.9 ± 3.7	20.2 ± 3.3	0.3 ± 0.3	57.8 ± 2.9	60.6 ± 1.4
15	24.0 ± 3.3	20.3 ± 5.4	0.23 ± 0.03	0.29 ± 0.04	13.4 ± 1.5	28.11 ± 3.8	9.0 ± 2.6	2.7 ± 0.9	50.0 ± 1.4	55.1 ± 0.9
16	24.4 ± 2.2	16.0 ± 1.2	0.13 ± 0.02	0.22 ± 0.02	11.3 ± 1.1	27.11 ± 4.7	52.2 ± 8.4	1.0 ± 0.6	49.3 ± 0.7	48.4 ± 3.6
ANOVA										
Environment	***[W]		NS		***		***		*	
Accession	***		***		NS		***		*	
Environment x Accession	***		***		NS		***		NS	
Accessions grouped by region										
Location	Field	Nursery	Combined		Field	Nursery	Field	Nursery	Combined	
South	45.4 ± 3.0[X]	23.0 ± 1.2	0.34 ± 0.02		11.3 ± 0.7[y]	23.1 ± 1.9	5.1 ± 1.8	0.06 ± 0.06	53.6 ± 0.8[z]	
Central	25.8 ± 2.3	17.1 ± 1.4	0.29 ± 0.02		12.2 ± 0.6	23.4 ± 1.6	18.0 ± 4.1	1.4 ± 0.3	56.2 ± 0.8	
North	21.2 ± 1.6	15.7 ± 1.0	0.20 ± 0.01		11.0 ± 0.7	23.3 ± 1.4	18.7 ± 3.2	2.2 ± 0.5	57.1 ± 0.9	
ANOVA										
Environment	***[z]		NS		***		***		NS	
Location	***		***		NS		*		NS	
Envir. x Loc.	***		NS		NS		NS		NS	

[T]Values represent mean (± standard errors) of 5 observations for the field environment and 3 observations for the nursery environment. [u]Environments combined when not significant to $P \leq 0.05$. [V]Values represent mean (± standard errors) internode extension of 15 observations for field environment and 9 observations for nursery environment. [W]NS,*,**,***Non-significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively. [X]Values represent means (± standard errors) of 21, 25, and 30 observations for south, central, and northern coast, respectively for field environment and observation of 15, 15, and 18 observations for south, central, and northern coast, respectively for nursery environment. [Y]Values represent means (± standard errors) internode extension of 108, 120, and 144 observations for south, central, and northern coast, respectively. [Z]Values represent means (± standard errors) flower diameter of 59, 102, and 107 observations for south, central, and northern coast, respectively.

Table 2a. Means of leaf measures by accession of *Oenothera drummondii* grown in both field and nursery conditions.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)		Serrations (No./leaf)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
1	25.8 ± 0.8^x	46.3 ± 1.3	10.7 ± 0.3^y	18.2 ± 0.6	4 ± 0.5	5.7 ± 0.2	1.9 ± 0.3	7.2 ± 0.5
2	23.7 ± 1.4	28.9 ± 0.7	10.7 ± 0.2	13.0 ± 0.3	2.8 ± 0.3	3.9 ± 0.4	2.4 ± 0.4	5.1 ± 0.5
3	29.8 ± 1.0	45.9 ± 1.6	11.2 ± 0.3	16.7 ± 0.7	4.5 ± 0.2	7.3 ± 0.4	4.9 ± 0.3	6.3 ± 0.5
4	27.3 ± 1.0	50.2 ± 1.2	10.1 ± 0.4	15.9 ± 0.4	3.6 ± 0.3	4.6 ± 0.4	2.6 ± 0.5	4.3 ± 0.3
5	24.9 ± 1.3	41.7 ± 0.9	7.9 ± 0.7	10.7 ± 0.4	2.3 ± 0.3	3.6 ± 0.3	2.3 ± 0.6	4.6 ± 0.5
6	24.3 ± 1.3	34.2 ± 0.5	10.7 ± 0.3	13.2 ± 0.5	2.3 ± 0.2	2.1 ± 0.3	1.2 ± 0.1	2.4 ± 0.3
7	32.6 ± 1.5	34.6 ± 0.6	13.4 ± 0.5	15.2 ± 0.7	3.5 ± 0.4	3.1 ± 0.3	5.9 ± 0.5	6.3 ± 0.5
8	39.7 ± 2.1	46.1 ± 0.5	12.4 ± 0.6	16.8 ± 0.4	3.8 ± 0.4	4.7 ± 0.3	8.7 ± 0.8	8.2 ± 0.4
9	36.3 ± 1.2	38.7 ± 1.8	11.3 ± 0.8	14.8 ± 0.4	2.5 ± 0.2	2.9 ± 0.2	8.6 ± 0.5	9.0 ± 0.6
10	31.0 ± 1.0	37.2 ± 1.6	10.7 ± 0.3	12.7 ± 0.8	2.6 ± 0.3	2.7 ± 0.4	8.7 ± 0.6	9.1 ± 0.6
11	24.8 ± 1.0	29.9 ± 0.7	10.0 ± 0.4	11.2 ± 0.3	2.3 ± 0.3	2.4 ± 0.2	10.9 ± 0.3	10.1 ± 0.5
12	31.7 ± 0.8	34.4 ± 1.0	10.8 ± 0.2	12.1 ± 0.4	3.1 ± 0.3	3.3 ± 0.2	10.0 ± 0.6	11.0 ± 0.9
13	37.9 ± 1.1	35.2 ± 1.6	11.1 ± 0.4	11.1 ± 0.8	3.7 ± 0.3	2.1 ± 0.4	5.7 ± 0.5	4.0 ± 0.7
14	25.7 ± 0.9	35.9 ± 1.7	10.4 ± 0.3	13.7 ± 0.4	2.6 ± 0.2	2.1 ± 0.2	4.9 ± 0.6	8.3 ± 0.3
15	29.2 ± 1.2	33.4 ± 1.2	9.5 ± 0.4	15.6 ± 0.5	2.1 ± 0.2	2.8 ± 0.2	4.4 ± 0.6	6.4 ± 0.5
16	26.3 ± 1.0	36.8 ± 1.7	10.2 ± 0.5	15.8 ± 0.3	2.3 ± 0.2	3.2 ± 0.4	6.3 ± 0.5	7.8 ± 0.4
ANOVA								
Environment	***		***		***		***	
Accession	***		***		***		***	
Environment x Accession	***		***		***		***	
Location	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
South	26.6 ± 0.5^y	43.7 ± 1	10.4 ± 0.2	14.9 ± 0.5	3.5 ± 0.2	4.6 ± 0.3	2.6 ± 0.2	5.0 ± 0.3
Central	30.3 ± 0.9	36.0 ± 1	11.2 ± 0.3	15.3 ± 0.3	2.9 ± 0.1	3.5 ± 0.2	5.5 ± 0.3	6.8 ± 0.3
North	31.2 ± 0.7	35.2 ± 0.7	10.7 ± 0.2	12.6 ± 0.3	2.8 ± 0.1	2.6 ± 0.1	8.2 ± 0.3	8.6 ± 0.4
ANOVA								
Environment	***^{z}		***		***		***	
Location	*		***		***		***	
Environment x Location	***		***		***		***	

^{x}Values represent mean (± standard errors) of 15 observations for the field environment and 9 observations for the nursery environment. ^{y}Values represent means (± standard errors) of 63, 75, and 90 observations for south, central, and northern coast, respectively for field environment and observations of 45, 45, and 54 for south, central, and northern coast, respectively for the nursery environment. ^{z} NS,*,**,***Non-significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2b. Maximum, minimum, mean, standard deviation, and coefficient of variation of growth measures combined for all accessions of *Oenothera drummondii* across environments of field and nursery.

Growth characteristic	Maximum	Minimum	Mean	Standard deviation	Coefficient of variation
Plant height (cm)	68	8	25.2[y]	13.3	53.0
Flower count	85	0	9.5	15.3	160.1
Height/width ratio	0.67	0.05	0.3	0.1	44.3
Ornamental rating	5	2	3.1	0.7	22.4
Internode length (mm)	52	1	16.1[z]	9.1	57.3
Flower diameter (mm)	79	35	56.0	8.2	14.7
Lamina length (mm)	56	17	32.9	7.9	24.1
Lamina width (mm)	21	2	12.1	2.8	22.9
Petiole length (mm)	11	1	3.2	1.4	45.0
Number of Teeth	15	1	6.2	3.3	52.9

[y]Means combined across all accessions and environments, n=124.
[z]Means combined across all accession and environments; n=372 for internode mean and n=268 for floral data.

Table 3. Correlation coefficients between morphological characteristics and collection location coordinates of *Oenothera drummondii* accessions from the Texas coast.

	Height	Flower count	Ht/W	Leaf length	Leaf width	Petiole length	# of leaf serrations	Orn. rating	Lat.	Long.
Height	1	0.05	0.56	-0.44	-0.33	-0.02	-0.55	0.28	-0.56	0.45
Flower count	0.05	1	-0.38	-0.39	-0.41	-0.23	0.17	0.3	0.25	-0.13
Height/widt h	0.56	-0.38	1	0.07	0.12	0.14	-0.44	-0.05	-0.5	0.38
Leaf length	-0.44	-0.39	0.07	1	0.74	0.53	0.29	-0.18	-0.03	-0.03
Leaf width	-0.33	-0.41	0.12	0.74	1	0.51	0.19	-0.01	-0.11	0.14
Petiole length	-0.02	-0.23	0.14	0.53	0.51	1	-0.01	0.06	-0.39	0.27
Number of leaf serrations	-0.55	0.17	-0.44	0.29	0.19	-0.01	1	-0.04	0.67	-0.62
Ornamental rating	0.28	0.3	-0.05	-0.18	-0.01	0.06	-0.04	1	-0.23	0.14
Latitude	-0.56	0.25	-0.5	-0.03	-0.11	-0.39	0.67	-0.23	1	-0.87
Longitude	0.45	-0.13	0.38	-0.03	0.14	0.27	-0.62	0.14	-0.87	1

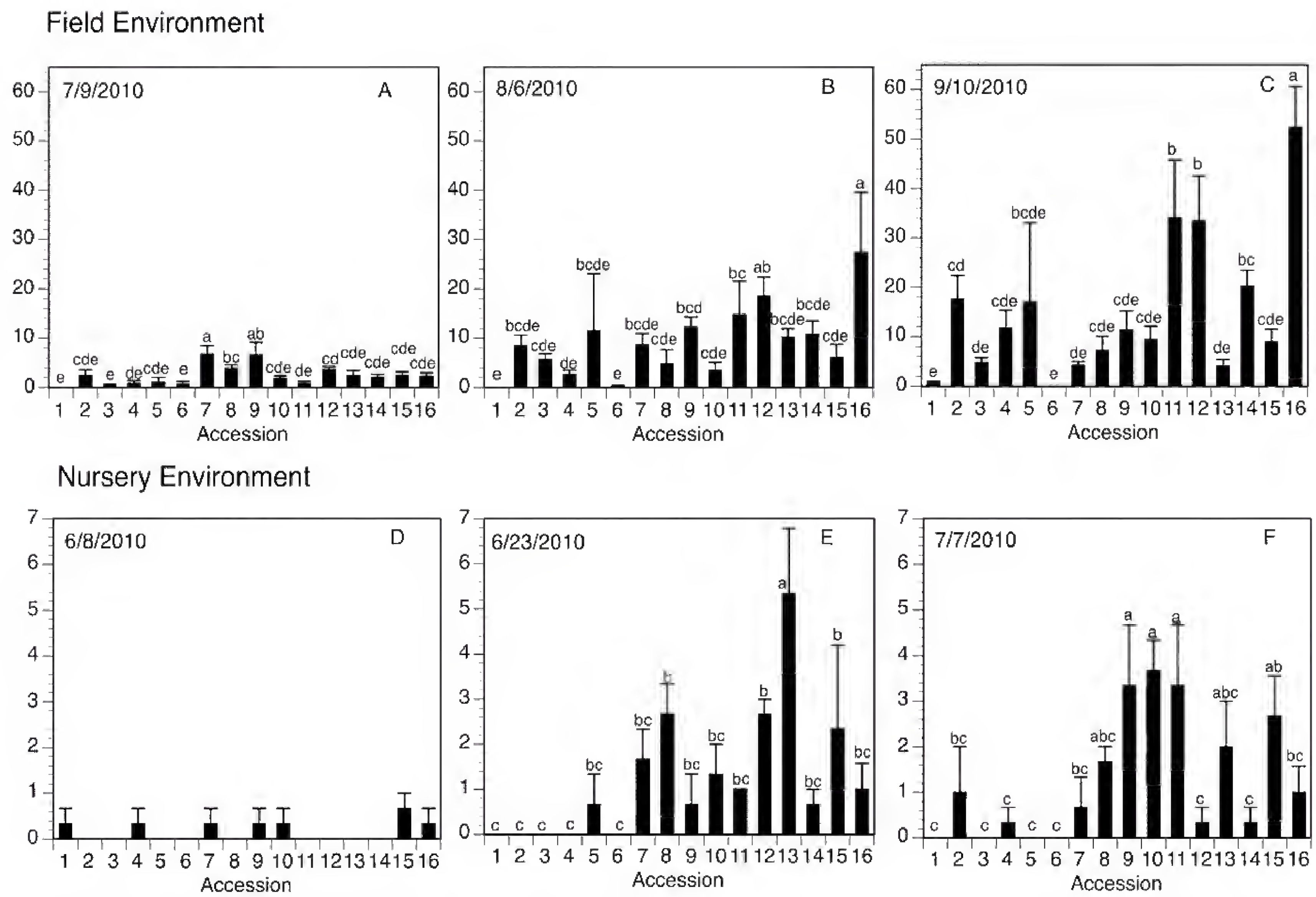

Fig. 2. Mean flower count of *Oenothera drummondii* on three sampling dates planted in field conditions or grown in 2.3 L containers in a nursery. Values represent mean (± standard errors) of 5 observations for the field environment and 3 observations for the nursery environment. There were no significant differences among accessions ($P \leq 0.05$) for sampling date 6 Jun 2010 (A). Any two means within a sampling date not followed by the same letter are significantly different at $P \leq 0.05$ using LSD mean separation.

Fig. 3. Example of *Oenothera drummondii* accessions exhibiting green foliage, blue foliage intact canopies and defoliated holes in canopy. Example of an *O. drummondii* exhibiting green foliage and defoliated holes in the canopy (A) and an example of an *O. drummondii* accession exhibiting blue foliage and an intact canopy (B).

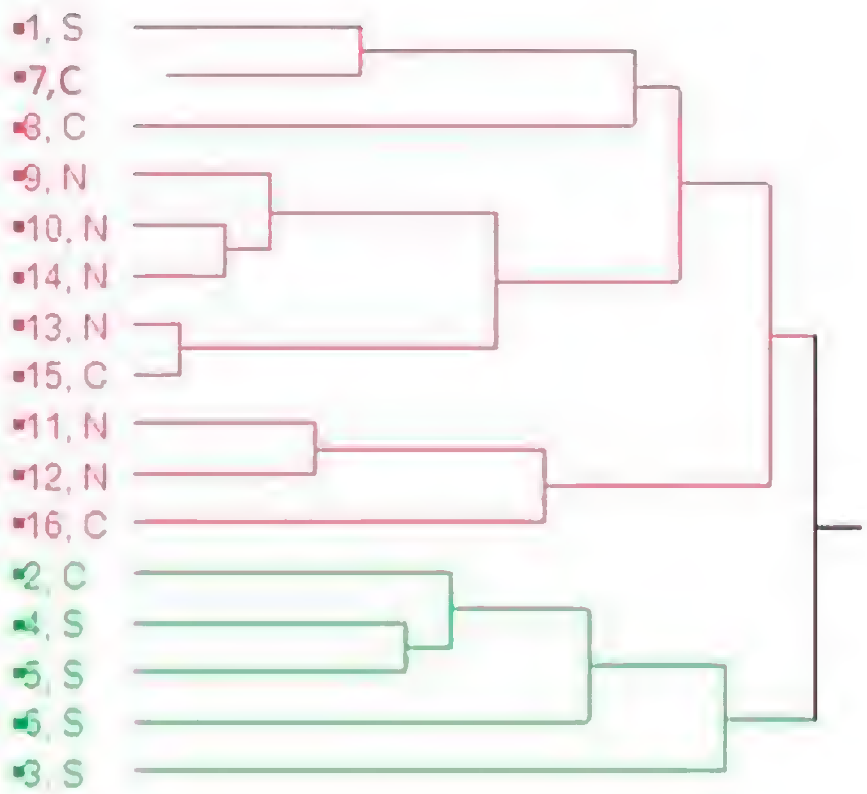

Fig. 4. Hierarchical Cluster analysis using Wards distance of *Oenothera drummondii* accessions based on morphological traits. Digits represent accession numbers of *O. drummondii* and letters the represent accessions' collection region along the coast S=Southern coast, C= Central coast, and N= Northern coast. Clusters separated by color.

Table 4. Means of growth measures separated by origin of *Oenothera drummondii* accession along Texas coast combined across both field and nursery environments.

Location	Height (cm)	Flower (No./plant)	Height:width ratio ($cm \cdot cm^{-1}$)
South	36.08a[v]	3.03b	0.34a
Central	22.56b	11.80a	0.24b
North	19.15b	12.52a	0.20b
ANOVA			
Location	***	***	***

[v] Values represent means of 21, 25, and 30 observations for south, central, and northern coast, respectively for field environment and observations of 15, 15, and 18 for south, central, and northern coast, respectively for nursery environment. Any two means within a column not followed by the same letter are significantly different at $P \leq 0.05$ using LSD mean separation.
[Z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

In general the southern forms of *O. drummondii* had a more upright and less spreading subshrub habit, whereas the plants from the central and northern areas had a shorter, more spreading groundcover growth form and a greater tendency to be free flowering. This will allow targeting collection efforts to regions based on characteristics and to potentially combine desirable traits via controlled crosses.

Borrichia frutescens

Significant ($P \leq 0.05$) differences existed among the accessions of *B. frutescens* (sea marigold) for height, height:width ratio, internode extension, flower count, flower diameter, leaf length leaf width, petiole length and number of serrations along the margin of the leaf (Tables 5 and 6). When the accessions were grouped by their region of collection along the Texas coasts, there were differences in height, flower count, flower diameter, internode extension, leaf length, leaf width, petiole length and the number serrations along the leaf margin (Tables 7 and 8).

Plant height ranged from a maximum of 78 cm to a minimum of 17 cm and had a coefficient of variation of 24.1%. Plants collected from the southern and central regions were on average shorter than *B. frutescens* collected from the northern coast. Environment affected mean plant height when accessions were grouped; based on collection location, mean height for plants grown in the field was 42 ± 0.9 cm and mean height for plants grown in the nursery was 45 ± 1.1 cm. Environment was a significant factor when analyzed as individual accessions instead of as part of the northern, central or southern collection zones. Plants could have been taller in the nursery due to ample water and nitrogen fertilizer. *Borrichia frutescens* has been reported to respond vigorously to increased fertility in container nursery production (King, 2015). Flower (inflorescence) count was variable among accessions, and highly significant for accession but not for environment (Table 5). Stability of flower production across growing environments could be an important attribute for acceptance of *B. frutescens* by the green industry and by consumers as a substitute for invasive exotic species. When grouped in collection areas, plants from the southern sites had a larger mean flower count of 5.2 flowers per plant compared to northern sites with 3.0 flowers per plant. Southern collection sites had larger flowers with a mean of 31.1 mm compared to 28.1 mm for plants collected from northern locations when planted in the field, but plants collected from northern locations had larger flowers than southern accessions when grown in the nursery (Table 5). Flower count was much more variable with a CV (coefficient of variation) of 106.4 than flower diameter with a CV of 14.2 (Table 9).

Leaf width, length, petiole and leaf margin serration were significantly different ($P \leq 0.05$) among regional groups and among accessions for *B. frutescens* (Table 6). Leaves tended to be larger in accessions for the central collection sites, with longer and wider leaf laminae (Table 8). The northern plants had longer petioles compared to plants collected from either the central or southern locations. The size of the leaves was different among field and nursery grown plants, with plants generally producing larger leaves when grown in the nursery (Table 6 and 8). The larger leaves were most likely the result of more favorable cultural conditions found in the nursery. Plants from the northern Texas coast had more entire margins on their leaves compared to plants collected from either the central or southern locations (Table 8).

Latitude was only significantly correlated with number of leaf serrations (r=-0.59); all other variables measured had correlation coefficients between 0.25 and -0.18. Longitude was positively correlated with the number of leaf serrations (r = 0.46) and petiole length (r = -0.32). Leaf lamina length was strongly correlated with leaf width (r = 0.70), petiole length (r = 0.65), and internode length (r = 0.46). Flower diameter was correlated with both leaf lamina length (r = 0.40) and leaf lamina width (r = 0.52).

Cluster analysis based on Wards method using all collected growth measures was not aligned ($P > 0.05$) with region of collection. Three clusters were developed and accessions from all three collection zones were randomly dispersed throughout.

Flower count was variable and significantly different ($P \leq 0.05$) among accessions. Flower diameter was also correlated with leaf width (r = 0.52). Southern accessions had more flowers and larger diameter flowers. Therefore, collections can be targeted for certain traits of interest and there is most likely a source of variation which exists for the creation of improved populations in the wild, though not all morphological measures may be correlated with the region of the Texas coast where plants are collected.

Table 5. Means *Borrichia frutescens* growth measures by accession when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)		Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)		Flower count (No./plant)	Flower diameter (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Combined[x]	Field	Nursery
1	43.0 ± 4.0[w]	50.0 ± 10.5	1.0 ± 0.2	1.1 ± 0.3	16.9 ± 1.0[y]	50.3 ± 3.2	2.0 ± 0.5	34.4 ± 0.0	33.2 ± 1.7
2	37.6 ± 2.8	37.0 ± 7.0	0.6 ± 0.1	0.9 ± 0.2	24.1 ± 1.6	52.4 ± 1.9	4.4 ± 1.0	30.7 ± 1.2	33.3 ± 2.3
3	56.6 ± 3.6	46.0 ± 6.8	1.4 ± 0.1	1.3 ± 0.3	21.4 ± 1.4	59.4 ± 3.4	3.4 ± 1.4	37.2 ± 1.0	35.8 ± 0.9
4	40.6 ± 1.3	47.7 ± 3.7	0.7 ± 0.0	1.1 ± 0.1	26.4 ± 1.4	46.9 ± 3.0	14.9 ± 3.4	28.9 ± 0.5	28.3 ± 0.6
5	36.6 ± 1.8	49.0 ± 1.2	1.0 ± 0.1	1.4 ± 0.1	20.4 ± 1.7	40.3 ± 1.3	2.9 ± 0.7	26.6 ± 0.7	26.5 ± 0.5
6	46.6 ± 1.7	42.0 ± 2.1	1.0 ± 0.1	1.4 ± 0.1	17.5 ± 0.7	44.6 ± 2.5	3.0 ± 0.7	29.3 ± 0.4	35.6 ± 0.5
7	37.8 ± 2.1	45.7 ± 4.3	1.1 ± 0.1	1.3 ± 0.2	20.7 ± 1.3	43.8 ± 1.3	3.8 ± 1.4	30.6 ± 0.0	29.3 ± 0.7
8	36.4 ± 2.4	45.3 ± 3.0	0.7 ± 0.1	1.2 ± 0.2	15.2 ± 2.0	41.3 ± 2.6	6.3 ± 2.4	0.0 ± 0.0	27.6 ± 0.7
9	44.4 ± 4.0	42.3 ± 5.4	0.8 ± 0.1	1.0 ± 0.2	17.8 ± 0.9	45.4 ± 2.6	4.0 ± 1.0	28.6 ± 1.2	29.7 ± 1.2
10	50.2 ± 2.9	46.7 ± 0.9	1.0 ± 0.1	1.5 ± 0.2	20.3 ± 1.7	43.3 ± 3.1	5.5 ± 2.1	34.0 ± 1.7	28.5 ± 0.6
11	43.2 ± 3.5	39.7 ± 5.9	0.8 ± 0.1	1.1 ± 0.2	20.3 ± 1.6	40.8 ± 2.5	8.0 ± 1.7	30.0 ± 0.7	34.0 ± 0.8
12	26.2 ± 3.1	31.3 ± 2.7	0.6 ± 0.1	0.7 ± 0.1	20.7 ± 1.5	49.7 ± 3.1	2.8 ± 0.6	31.3 ± 1.2	29.4 ± 0.5
13	36.2 ± 2.2	33.0 ± 2.1	0.6 ± 0.0	0.6 ± 0.1	18.3 ± 1.7	50.4 ± 3.0	3.1 ± 1.0	27.0 ± 0.6	0.0 ± 0.0
14	40.2 ± 2.1	45.0 ± 1.2	0.9 ± 0.1	1.1 ± 0.1	17.3 ± 1.4	39.9 ± 2.0	1.5 ± 0.3	27.6 ± 2.1	32.3 ± 1.8
15	44.4 ± 2.3	56.7 ± 0.9	0.8 ± 0.1	1.4 ± 0.1	17.9 ± 1.4	40.3 ± 1.5	3.4 ± 0.5	21.8 ± 0.6	30.0 ± 1.1
16	32.0 ± 2.3	38.7 ± 2.9	0.7 ± 0.1	1.1 ± 0.0	15.2 ± 1.5	46.7 ± 2.8	5.8 ± 1.2	26.0 ± 1.0	27.2 ± 0.9
17	40.2 ± 3.8	52.0 ± 8.6	0.9 ± 0.1	1.3 ± 0.3	15.3 ± 1.7	47.2 ± 3.3	2.4 ± 0.3	27.3 ± 1.5	26.7 ± 0.9
18	49.4 ± 2.1	48.3 ± 0.7	0.9 ± 0.0	1.6 ± 0.2	18.6 ± 1.0	39.9 ± 1.5	6.8 ± 1.4	27.5 ± 0.7	27.1 ± 0.7
19	48.6 ± 1.1	51.7 ± 4.9	0.9 ± 0.1	1.3 ± 0.1	16.3 ± 0.9	44.1 ± 1.2	3.9 ± 1.0	27.4 ± 0.6	34.2 ± 1.5
20	69.8 ± 2.9	63.3 ± 0.3	0.9 ± 0.0	1.7 ± 0.1	18.0 ± 1.2	39.2 ± 2.0	2.1 ± 1.0	28.6 ± 1.5	0.0 ± 0.0
21	37.0 ± 3.4	43.7 ± 4.7	0.6 ± 0.1	1.0 ± 0.1	11.8 ± 1.3	48.2 ± 2.2	0.8 ± 0.3	0.0 ± 0.0	33.3 ± 2.7
22	41.6 ± 3.4	45.0 ± 5.3	0.8 ± 0.1	0.9 ± 0.2	18.6 ± 2.3	52.2 ± 2.7	4.1 ± 1.0	27 ± 1.3	32.0 ± 1.1
23	58.2 ± 1.9	63.3 ± 1.7	1.3 ± 0.1	1.7 ± 0.2	16.8 ± 1.6	48.7 ± 3.0	0.9 ± 0.4	28.4 ± 3.2	0.0 ± 0.0
24	34.6 ± 5.0	29.7 ± 4.2	1.0 ± 0.1	1.0 ± 0.1	14.3 ± 1.4	37.4 ± 2.7	6.6 ± 2.0	25.4 ± 0.8	30.3 ± 1.2
26	43.4 ± 3.7	49.3 ± 2.3	0.8 ± 0.1	1.2 ± 0.1	18.6 ± 0.9	57.0 ± 3.3	2.0 ± 0.8	32.6 ± 1.6	37.0 ± 0.6
27	39.0 ± 2.2	42.3 ± 1.2	1.0 ± 0.1	1.2 ± 0.0	13.7 ± 1.0	43.0 ± 2.9	4.3 ± 0.8	29.2 ± 0.7	30.6 ± 1.3
28	33.2 ± 2.9	40.7 ± 2.8	0.7 ± 0.0	1.1 ± 0.1	12.6 ± 1.8	44.9 ± 1.6	6.8 ± 1.9	29.1 ± 0.9	28.5 ± 0.5
Environment	**[z]		***		***		NS	***	
Accession	***		***		***		***	***	
Environment x Accession	NS		**		***		NS	***	

[w]Values represent mean (± standard errors) of 5 observations for field environment and 3 observations for nursery environment. [x]Environments combined when not significant to $P \leq 0.05$. [y]Values represent mean (± standard errors) internode extension of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 6. Mean of leaf measures by accession for *Borrichia frutescens* when grown in 2.3 L containers in the nursery or planted to the field.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)		Teeth/serrations (No./leaf)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
1	36.8 ± 0.9[y]	41.3 ± 1.8	13.5 ± 0.7	23.6 ± 1.7	4 ± 0.2	6.1 ± 0.4	12.1 ± 1	19.7 ± 1.8
2	38.8 ± 1.6	39.4 ± 1.6	18.6 ± 1.3	24 ± 2.3	6.3 ± 0.3	6.6 ± 0.4	6 ± 1.4	15.1 ± 1.8
3	36.6 ± 0.7	39.6 ± 1.1	16.9 ± 0.6	29 ± 1.4	6.1 ± 0.3	6.2 ± 0.3	6.1 ± 0.9	17 ± 2.1
4	31.2 ± 1.1	41.1 ± 1.1	9.8 ± 0.4	19.2 ± 1.3	4.4 ± 0.2	5.9 ± 0.4	1.7 ± 0.5	10.9 ± 2.2
5	27 ± 0.7	29.8 ± 0.7	11.6 ± 0.5	16.2 ± 1.1	3.9 ± 0.2	5.1 ± 0.3	13.5 ± 1.1	18 ± 0.9
6	37.9 ± 1.5	40.4 ± 0.9	15.6 ± 0.9	28 ± 1.3	5.6 ± 0.2	6.8 ± 0.3	5.4 ± 0.9	15.9 ± 1.6
7	31 ± 1.3	36.3 ± 2.3	8.9 ± 0.5	16.9 ± 1.3	4.3 ± 0.2	6 ± 0.3	9.5 ± 1.2	19.3 ± 0.7
8	23.7 ± 0.8	26.8 ± 0.7	10.1 ± 0.5	15.1 ± 1	3.9 ± 0.2	5.7 ± 0.4	11.7 ± 1.2	16.9 ± 1.3
9	35.4 ± 1.2	36.2 ± 2	14.8 ± 0.6	19.1 ± 1.7	4.5 ± 0.2	6.4 ± 0.5	14.5 ± 0.8	14.2 ± 1
10	43.7 ± 1.2	35.1 ± 1.4	26.0 ± 1.0	25.4 ± 1.7	7.2 ± 0.5	6.2 ± 0.5	26.7 ± 1.3	23.9 ± 2.5
11	31.4 ± 1.4	38.2 ± 1.3	11.8 ± 0.7	24.4 ± 1.8	5 ± 0.3	6.9 ± 0.3	2.5 ± 0.6	15.6 ± 1.8
12	32.3 ± 1.3	39.3 ± 1.5	10.9 ± 0.7	21.7 ± 1.3	4.5 ± 0.3	7.3 ± 0.5	2.7 ± 0.3	12.8 ± 1.5
13	35.9 ± 0.9	39.3 ± 1.6	10.2 ± 0.3	16.8 ± 1.4	5.5 ± 0.2	8.2 ± 0.5	1.1 ± 0.1	6.8 ± 1.2
14	37.8 ± 1.4	39.6 ± 1.4	16 ± 1.3	24.2 ± 2.3	6 ± 0.4	8 ± 0.4	1.5 ± 0.4	15.1 ± 2.5
15	35.9 ± 1.1	38.4 ± 1.3	11.9 ± 0.8	19.2 ± 1.3	4.3 ± 0.3	5.9 ± 0.3	1.6 ± 0.4	4.2 ± 0.5
16	32 ± 1.4	42.2 ± 2.3	7.6 ± 0.5	20.1 ± 1.6	4.8 ± 0.3	8.4 ± 0.5	2.0 ± 0.6	11.2 ± 1.1
17	29.1 ± 1.9	37.4 ± 1.5	11.7 ± 0.8	19.7 ± 1.4	4.6 ± 0.2	6.8 ± 0.3	2.1 ± 0.7	6.3 ± 1.2
18	37.8 ± 1.2	41.8 ± 1.6	13.5 ± 0.7	23.8 ± 0.6	5.5 ± 0.2	6.8 ± 0.4	5.2 ± 1.3	14.2 ± 1
19	34.4 ± 1.2	39.3 ± 1.7	13.6 ± 0.7	22.6 ± 1.8	4.9 ± 0.3	6.7 ± 0.3	2.3 ± 0.5	14.4 ± 1.4
20	32 ± 1.1	36.3 ± 1.4	15.8 ± 0.7	23.7 ± 0.9	6 ± 0.3	8.1 ± 0.5	1.0 ± 0.0	2 ± 0.3
21	31.6 ± 1.3	42.4 ± 1.2	9.7 ± 0.7	22 ± 1.1	4.6 ± 0.2	7.8 ± 0.3	1.0 ± 0.0	2.3 ± 0.3
22	30.2 ± 1.1	35.3 ± 1.4	12.3 ± 0.6	18.1 ± 1.4	6.6 ± 0.3	8.4 ± 0.5	1.3 ± 0.3	8 ± 1.9
23	36 ± 1.1	43.4 ± 1.9	13.9 ± 0.6	20.1 ± 1.1	5.6 ± 0.3	8.7 ± 0.5	1.0 ± 0.0	5.9 ± 1.2
24	26.7 ± 1.0	32.7 ± 1	11.1 ± 0.6	20.6 ± 1.6	4.2 ± 0.2	6.9 ± 0.4	1.0 ± 0.0	3.1 ± 0.5
26	42.1 ± 1.7	40.1 ± 0.9	15.9 ± 0.9	20.8 ± 1.3	7 ± 0.4	8.1 ± 0.4	1.1 ± 0.1	1.6 ± 0.2
27	29.2 ± 1	35.9 ± 1.4	11.1 ± 0.6	21.8 ± 1.6	4.8 ± 0.1	6.2 ± 0.4	4.6 ± 0.7	14.9 ± 1.8
28	33.1 ± 1.7	41 ± 1.1	12.2 ± 0.8	21.3 ± 1.3	4.2 ± 0.2	5.9 ± 0.3	1.2 ± 0.2	5.8 ± 1.2
ANOVA								
Environment	***[z]		***		***		***	
Accession	***		***		***		***	
Environment x Accession	***		***		***		***	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.

[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 7. Mean of growth measures separated by origin of accession along Texas coast for *Borrichia frutescens* when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)	Flower count (No./plant)	Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)		Flower diameter (mm)	
Location	Combined [u]	Combined	Field	Nursery	Field	Nursery	Field	Nursery
South	42.6 ± 1.2b	5.2 ± 0.5a	0.9 ± 0.0 [v]	1.2 ± 0.1	20.0 ± 0.5	46.1 ± 1.0	31.1 ± 0.5[x]	29.8 ± 0.5
Central	42.5 ± 1.0b	4.4 ± 0.4ab	0.8 ± 0.0	1.1 ± 0.1	17.5 ± 0.5	45.2 ± 0.8	27.6 ± 0.5	30.5 ± 0.6
North	46.9 ± 1.3a	3.0 ± 0.6b	0.9 ± 0.0	1.2 ± 0.1	16.0 ± 0.6[x]	46.5 ± 1.1	28.1 ± 0.7	31.8 ± 0.7
ANOVA								
Environment	NS[z]	NS	***		***		***	
Location	*	*	NS		*		**	
Environment x Location	NS	NS	NS		NS		***	

[u]Environments combined when not significant to $P \leq 0.05$. Values represent means (± standard errors) of 72, 88, and 56 observations for south, central, and northern coasts, respectively.
[v]Values represent means (± standard errors) of height: width ratio of 45, 55, and 35 observations for south, central, and northern coasts, respectively for field environment and observations of 27, 33, and 21 for south, central, and northern coasts, respectively for nursery environment.
[x]Values represent means (± standard errors) of internode extension for 135, 164, and 104 observations for south, central, and northern coasts, respectively for field environment and of 81, 99, and 63 observations for south, central, and northern coasts, respectively for nursery environment.
[y]Values represent means (± standard errors) of flower diameter for 57, 73, and 37 observations for south, central, and northern coasts, respectively for field environment and 60, 53, and 32 observations for south, central, and northern coasts, respectively for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 8. Mean of leaf measures separated by origin of accession along Texas coast for *Borrichia frutescens* when grown in 2.3 L containers in the nursery or planted to the field.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)		Teeth/serrations (No./leaf)	
Location	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
South	33.2 ± 0.6[y]	36.1 ± 0.7	13.8 ± 0.5	21.2 ± 0.7	5.0 ± 0.1	6.2 ± 0.1	10.2 ± 0.7	16.5 ± 0.7
Central	34.9 ± 0.5	39.8 ± 0.5	12.8 ± 0.3	21.8 ± 0.5	5.0 ± 0.1	6.9 ± 0.1	3.4 ± 0.3	11.7 ± 0.6
North	32.5 ± 0.6	38.0 ± 0.7	12.8 ± 0.3	21.0 ± 0.5	5.5 ± 0.1	7.7 ± 0.2	1.6 ± 0.2	5.4 ± 0.7
ANOVA								
Environment	***[z]		***		***		***	
Location	*		***		***		***	
Environment x Location	***		***		***		***	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 9. Maximum, minimum, mean, standard deviation, coefficient of variation of growth measures combined for all accessions across all environments for accessions of *Borrichia frutescens*.

	Maximum	Minimum	Mean	Standard Deviation	CV[x]
Plant height (cm)	78	17	43.6[y]	10.5	24.1
Flower count	34	0	4.3	4.5	106.4
Height:width ratio	2.0	0.3	1.0	0.3	33.8
Ornamental rating	5	2	3.1	0.8	24.2
Growth index (cm^3)	507744.0	9500	81276.5	64607.0	79.5
Internode length (mm)	73.0	2.3	28.5[z]	15.4	54.2
Flower diameter (mm)	42.53	18.1	29.7	4.2	14.2
Pedicle length (mm)	76.0	14.0	38.3	11.7	30.5
Lamina length (mm)	57.0	18.4	35.4	6.6	18.6
Lamina width (mm)	37.0	3.9	16.2	6.3	38.8
Petiole length (mm)	12.0	2.6	5.8	1.7	28.6
Teeth/serrations (no./plant)	37	1	7.6	7.5	98.6

[x]Coefficient of Variation.
[y]Means combined across all accessions and environments, N=216.
[z]Means combined across all accession and environments N=646 for internode mean and N=312 for floral data.

Erigeron procumbens

Significant differences ($P \leq 0.05$) in height, height:width ratio, internode extension, lamina length, lamina width and petiole length were found among accessions and regional collection of *E. procumbens* (Corpus Christi fleabane) (Table 10 and 13). This species primarily blooms in cooler seasons in warm climates such as Texas (Arnold, 2011). There were no differences among collections ($P > 0.05$) in flower (inflorescence) count, though floral analyses were constrained by small sample size on the date of data collection. There was only one accession collected from the northern region of the Texas coast. This is to be expected, encountering *E. procumbens* in this region would be rarer due to this being the extreme northern end of its natural range. In statistical analysis with a regional effect, only the southern and central regions were considered because of the small sample size from the northern region.

Accessions from the southern collection region in the vicinity of Brownsville were taller in both the nursery and field environment (Table 11). Plants from the southern collection region also had a larger height:width ratio when grown in containers (Table 11) than *E. procumbens* from the other collection area. This greater height:width ratio indicated that plants were not only taller but also had less of a prostrate habit than the wild accessions collected from the central coast of the Texas.

All leaf growth measures of *E. procumbens* were different ($P \leq 0.05$) among the accessions and between the collection groups (Tables 13 and 14). Plants collected from the southern collection region had larger leaves in both length and width of the leaf laminae. There was only an interaction among environments and regions of collection for leaf width; plants collected from the central Texas coast had a much larger increase in leaf width when grown in containers than in the field. On the accession level, most plants had larger leaves in terms of width, length, and petiole length when grown in the nursery environment (Table 13). This could be explained by the more favorable cultural conditions provided by the nursery compared to the field. The interaction among accessions and environments for *E. procumbens* could be explained by not all accessions being equally plastic in phenotype. Differences in plasticity are shown by not all accessions having similar increases in leaf size (Table 13). Some accessions of *E. procumbens* increased leaf size by 53% when grown in the nursery and other accessions (e.g. 18) only increased leaf size by 4 % when grown in nursery conditions compared to the field.

Table 10. Means of *Erigeron procumbens* growth measures by accession when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)		Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery
1	5.8 ± 0.4	11.0 ± 3.2	0.1 ± 0.0	0.2 ± 0.1	16.2 ± 1.5	28.8 ± 3.7
2	7.0 ± 1.4	8.7 ± 1.2	0.1 ± 0.0	0.2 ± 0.0	17.9 ± 1.2	22.6 ± 1.0
3	5.4 ± 0.5	6.3 ± 0.7	0.1 ± 0.0	0.1 ± 0.0	13.6 ± 0.9	19.4 ± 2.0
4	6.5 ± 1.3	8.7 ± 2.3	0.1 ± 0.0	0.2 ± 0.0	11.4 ± 1.5	18.4 ± 2.6
5	10.8 ± 2.1	11.7 ± 1.9	0.1 ± 0.0	0.2 ± 0.0	15.0 ± 1.3	17.0 ± 1.0
6	4.2 ± 0.9	6.3 ± 0.3	0.1 ± 0.0	0.1 ± 0.0	16.6 ± 1.6	24.2 ± 2.4
7	5.6 ± 0.7	7.3 ± 1.5	0.1 ± 0.0	0.1 ± 0.0	18.0 ± 1.0	24.9 ± 3.1
8	6.8 ± 0.7	9.3 ± 1.5	0.1 ± 0.0	0.2 ± 0.0	15.1 ± 0.9	22.9 ± 2.4
9	6.2 ± 0.4	10.3 ± 1.9	0.1 ± 0.0	0.2 ± 0.0	13.5 ± 0.8	20.1 ± 1.7
10	7.8 ± 1.4	7.7 ± 1.2	0.1 ± 0.0	0.1 ± 0.0	15.5 ± 1.1	23.8 ± 2.8
11	9.0 ± 1.3	14.0 ± 1.5	0.1 ± 0.0	0.3 ± 0.0	14.9 ± 1.5	17.3 ± 1.2
12	4.8 ± 0.7	6.7 ± 0.3	0.1 ± 0.0	0.1 ± 0.0	15.1 ± 1.4	22.8 ± 1.4
13	5.0 ± 0.8	7.0 ± 0.6	0.0 ± 0.0	0.1 ± 0.0	17.7 ± 0.7	23.8 ± 2.1
15	7.4 ± 1.6	5.3 ± 0.9	0.1 ± 0.0	0.1 ± 0.0	21.9 ± 2.2	25.9 ± 2.0
16	4.6 ± 0.5	5.0 ± 0.6	0.1 ± 0.0	0.1 ± 0.0	13.8 ± 1.2	21.7 ± 1.5
17	5.2 ± 0.8	8.7 ± 0.9	0.1 ± 0.0	0.2 ± 0.0	18.7 ± 2.2	25.6 ± 1.8
18	6.8 ± 0.6	7.0 ± 0.6	0.1 ± 0.0	0.1 ± 0.0	11.9 ± 1.0	18.8 ± 1.0
ANOVA						
Environment	***[z]		***		***	
Accession	***		***		***	
Environment x Accession	NS		*		NS	

Values represent mean (± standard errors) of 5 observations for field environment and 3 observations for nursery environment.
[x]Environments combined when not significant to $P \leq 0.05$.
[y]Values represent mean (± standard errors) internode extension of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Ornamental ratings of *E. procumbens* were different among the accessions (Chi square P=0.02) and the two regional collection (Chi square P=0.01) groups. The accessions and plants collected from the southern region tended to have a greater ornamental rating than *E. procumbens* from the central Texas coast in both the field and nursery environments.

There were differences in height, height:width ratio, ornamental rating, internode extension, lamina length, lamina width and petiole length among accessions and regional collections of *E. procumbens*. The relatively low CV for ornamental characteristics of interest such as height, height:width ratio, and ornamental rating (Table 12) indicate there is little variability for selection. Flower (inflorescence) count was not significant among accessions or regional collection groups in this study. The lack of differences in flower count could be due to the tendency of *E. procumbens* to flower in flushes, peaking during the cooler spring temperatures (Arnold, 2011).

Sesuvium portulacastrum

Height, height:width ratio, flower count, flower diameter, internode, leaf length, leaf width, petiole length, and stem diameter were different ($P \leq 0.05$) among *S. portulacastrum* (sea purslane) accessions (Tables 15 and 16). When grouped based on region of collection along the Texas coast, there were differences ($P \leq 0.05$) among the regions for height, flower diameter, leaf length, leaf width, petiole length and stem diameter. Only flower count, height:width ratio, growth index, and pedicle length had highly variable traits with CVs near 100 (Table 17).

Table 11. Means of growth measures separated by origin of accession along Texas coast for *E. procumbens* when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)		Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)	
Location	Field	Nursery	Field	Nursery	Field	Nursery
South[x]	7.7 ± 0.6[y]	10.1 ± 0.8	0.1 ± 0[y]	0.2 ± 0	15.33 ± 0.47	21 ± 0.95
Central	5.6 ± 0.3	7.4 ± 0.5	0.1 ± 0	0.1 ± 0	16.4 ± 0.51	23.31 ± 0.72
North	6.8 ± 0.6	7 ± 0.6	0.1 ± 0	0.1 ± 0	11.9 ± 0.95	18.78 ± 1
ANOVA						
Environment	***[z]		***		***	
Location	***		***		***	
Environment x Location	NS		*		NS	

[x]Location is for Central and Southern Region only, due to the lack of samples from Northern Region.
[y]Values represent mean (± standard errors) of 5 observations for field environment and 3 observations for nursery environment for height, height /width ratio. Means (± standard errors) for internode extension represent 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Although all *S. portulacastrum* had low spreading groundcover type habits, plants collected from the southern region, like southern accessions of *O. drummondii*, were on average 69 % taller than plants collected from the northern range (Table 18). Most of this increase in the average height could be explained by accession 1 and accession 7, with mean heights when grown in the field of 14.4 ± 0.9 cm and 24.2 ± 1.6 cm, respectively (Table 15). There was not a significant environmental effect ($P > 0.05$), but there was an interaction ($P \leq 0.05$) between environment and accession. All but one accession of *S. portulacastrum* collected from the southern coast decreased in mean height when grown in the nursery environment. This decrease in height ranged from 13 % for accession 4 to 40 % for accession 5 (Table 15). In contrast, all *S. portulacastrum* accessions collected from the northern region range had taller mean heights when grown in the nursery. One accession, accession 10, increased nursery height 60 % compared to field conditions (Table 15).

Internode extension of *S. portulacastrum* was generally greater in the nursery environment, most likely from favorable cultural conditions. Not all accessions were equally plastic. For example, accession 1 only increased internode extension by 66 %, whereas accession 6 increased internode extension by 220 % when grown in the nursery compared to the field (Table 15). This difference in plasticity of internode extension would explain the accession x environment interaction. The region of collection had no effect on the internode extension in this study.

Table 12. Maximum, minimum, mean, standard deviation, coefficient of variation of growth measures combined for all accessions across all environments for accession of *Erigeron procumbens*.

	Maximum	Minimum	Mean	Standard Deviation	CV[x]
Plant height (cm)	19.0	2.0	7.1[y]	3.0	41.9
Flower count	34	0	8.9	8.7	97.3
Height/width ratio	0.3	0.02	0.1	0.1	62.5
Ornamental rating	5	1	3.13	0.7	21.3
Growth index ($cm^{3)}$	327750.0	580.0	50548.7	47062.4	93.1
Internode length (mm)	53.0	2.1	18.3	6.8	36.9
Flower diameter (mm)	25.0	15.0	19.5	2.2	11.1
Pedicle length (mm)	184	81	121.0	21.6	17.8
Lamina length (mm)	31.0	8.7	19.2	4.3	22.3
Lamina width (mm)	24.0	5.3	12.1	3.0	25.0
Petiole length (mm)	13.4	2.7	6.8	2.0	29.2

[x]Coefficient of variation.
[y]Means combined across all accessions and environments, N=135.
[z]Means combined across all accession and environments N=387 for internode mean and N=59 for floral data.

There were differences ($P \leq 0.05$) in leaf lamina length, leaf lamina width, petiole length, and stem diameter of *S. portulacastrum* on the regional and accession levels. Accessions of *S. portulacastrum* from the southern region had longer leaves, wider leaves, longer petioles and thicker stems than accessions from either the central or northern collection areas (Table 19). Like internode extension, leaf measures generally increased when *S. portulacastrum* were grown in the nursery environment, with some genotypes like accession 6 increasing leaf length 51 % and leaf width 24 % in the nursery environment (Table 16).

Accessions 11, 12, and 15 exhibited decreases in leaf measures in the nursery environment compared to the field. Leaf length was correlated with leaf width (r=0.59) and internode extension (r=0.53). Leaf width was strongly correlated with latitude of collection site (r=-0.59) and stem diameter (r=0.83). These changes in leaf size indicate that *S. portulacastrum* leaves are plastic in response to environmental conditions.

Flower count of *S. portulacastrum* was not affected ($P > 0.05$) by region of collection, but there were differences ($P \leq 0.05$) among accessions, with a strong environmental effect. Accessions flowered more in the field than in the nursery environment. This is most likely because *S. portulacastrum* were larger in the field than in the nursery due to a longer growing season. Even though fewer flowers were produced in the nursery, the nursery flowers were larger for most accessions of *S. portulacastrum* compared to flowers of plants grown in the field. Flower diameter was correlated to stem diameter (r=0.52). Some accessions, such as 4 and 15, produced smaller flowers in the nursery than in the field (Table 15).

Table 13. Means of leaf measures by accession of *Erigeron procumbens* when grown in 2.3 L containers in the nursery or planted to the field.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery
1	18.9 ± 1.8	21.4 ± 1.6	11.1 ± 0.9	15.2 ± 1.0	8.4 ± 0.8	9.3 ± 0.4
2	15.6 ± 0.7	20.8 ± 1.0	10.6 ± 0.5	14.7 ± 0.6	4.5 ± 0.3	7.2 ± 0.1
3	16.7 ± 0.8	21.6 ± 1.3	10.8 ± 0.5	14.2 ± 0.8	5.8 ± 0.4	7.6 ± 0.4
4	16.6 ± 0.6	21.8 ± 0.9	12.0 ± 0.4	15.4 ± 0.6	6.2 ± 0.5	7.2 ± 0.5
5	20.3 ± 0.7	22.3 ± 0.9	12.6 ± 0.5	14.3 ± 0.9	8.0 ± 0.5	8.2 ± 0.5
6	18.9 ± 1.4	23.4 ± 1.3	11.4 ± 0.9	14.6 ± 0.6	6.0 ± 0.6	6.6 ± 0.3
7	18.5 ± 0.9	21.1 ± 0.8	12.0 ± 0.4	14.7 ± 0.5	7.2 ± 0.4	8.0 ± 0.4
8	15.5 ± 0.7	21.7 ± 0.4	11.5 ± 0.5	16.0 ± 0.7	5.0 ± 0.4	7.2 ± 0.3
9	17.6 ± 0.9	23.8 ± 1.1	10.0 ± 0.7	13.1 ± 0.9	6.4 ± 0.4	9.0 ± 0.6
10	17.4 ± 1.1	22.3 ± 1.2	9.7 ± 0.4	11.8 ± 1.0	5.5 ± 0.5	7.6 ± 0.9
11	20.9 ± 1.1	22.4 ± 0.9	11.7 ± 0.7	12.1 ± 0.8	8.0 ± 0.4	9.2 ± 0.7
12	12.6 ± 1.0	19.3 ± 1.4	7.2 ± 0.3	10.1 ± 0.7	4.1 ± 0.3	5.4 ± 0.3
13	17.7 ± 0.8	25.4 ± 1.1	10.5 ± 0.6	16.6 ± 1.3	5.4 ± 0.3	9.3 ± 0.5
15	18.3 ± 0.8	22.4 ± 0.6	11.0 ± 0.6	15.4 ± 0.8	6.9 ± 0.3	7.2 ± 0.1
16	17.0 ± 1.1	18.9 ± 1.0	10.2 ± 0.6	12.9 ± 0.7	6.2 ± 0.4	6.7 ± 0.3
17	17.4 ± 1.1	19.3 ± 0.8	12.2 ± 0.6	14.3 ± 0.7	5.6 ± 0.3	6.8 ± 0.3
18	18.8 ± 1.2	19.6 ± 0.7	10.0 ± 0.6	11.0 ± 0.7	6.7 ± 0.5	6.8 ± 0.5
ANOVA						
Environment	***[z]		***		***	
Accession	***		***		***	
Environment x Accession	*		*		***	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 14. Means of leaf measures separated by origin of *Erigeron procumbens* accession along Texas coast when grown in 2.3 L containers in the nursery or planted to the field.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)	
Location	Field	Nursery	Field	Nursery	Field	Nursery
South	18.37 ± 0.41	22.28 ± 0.38	11.23 ± 0.25	13.67 ± 0.38	6.68 ± 0.21	8.2 ± 0.25
Central	16.96 ± 0.35	21.44 ± 0.39	10.69 ± 0.22	14.34 ± 0.30	5.86 ± 0.16	7.33 ± 0.16
North	18.75 ± 1.17	19.56 ± 0.73	10.00 ± 0.58	11.00 ± 0.69	6.71 ± 0.47	6.78 ± 0.46
ANOVA						
Environment	***[z]		***		***	
Location	***		NS		***	
Environment x Location	NS		***		NS	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 15. Means of *Sesuvium portulacastrum* growth measures by accession when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)		Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)		Flower count (No./plant)		Flower diameter (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
1	14.4 ± 0.9[x]	11.7 ± 1.5	0.09 ± 0.01	0.26 ± 0.06	44.2 ± 3.9[y]	73.5 ± 9.6	20.8 ± 7.7	3.3 ± 0.9	14.6 ± 0.9	19.3 ± 0.3
2	10.8 ± 2.1	8.0 ± 3.0	0.08 ± 0.02	0.10 ± 0.04	40.8 ± 3.6	79.9 ± 6.1	16.8 ± 4.6	3.3 ± 0.7	15.6 ± 0.3	17.5 ± 0.5
3	14.2 ± 1.2	8.0 ± 0.6	0.10 ± 0.01	0.10 ± 0.01	25.3 ± 3.1	61.4 ± 5.1	21.8 ± 3.2	18.0 ± 7.5	13.2 ± 1.1	15.5 ± 0.6
4	8.4 ± 0.4	7.3 ± 0.7	0.04 ± 0.00	0.13 ± 0.01	26.3 ± 1.5	54.6 ± 1.7	40.2 ± 19.9	13.0 ± 1.0	16.4 ± 0.5	15.3 ± 0.4
5	12.0 ± 1.7	7.3 ± 1.2	0.06 ± 0.01	0.14 ± 0.03	20 ± 1.2	41 ± 4.2	185.0 ± 42.7	0.7 ± 0.3	15 ± 0.5	16.4 ± 0.2
6	12.7 ± 1.2	13.3 ± 2.0	0.13 ± 0.05	0.15 ± 0.02	30.2 ± 3.7	97.6 ± 5.8	14.7 ± 7.7	0.3 ± 0.3	18 ± 1.1	18.5 ± 0.6
7	24.2 ± 1.6	20.3 ± 1.9	0.18 ± 0.02	0.26 ± 0.02	45.7 ± 2.3	107.2 ± 4.7	15.4 ± 1.8	10.7 ± 0.7	20.4 ± 0.6	19.2 ± 0.5
8	10.4 ± 0.9	12.3 ± 2.3	0.07 ± 0.01	0.13 ± 0.02	27.4 ± 2.0	76.1 ± 2.8	55.6 ± 12.3	11.0 ± 3.5	17.7 ± 0.5	19.6 ± 0.7
9	8.0 ± 1.2	10.0 ± 2.0	0.06 ± 0.00	0.13 ± 0.04	26.9 ± 3.2	54 ± 4.1	67.7 ± 30.6	9.0 ± 2.9	16 ± 0.9	15 ± 0.4
10	5.8 ± 1.1	9.3 ± 1.3	0.03 ± 0.00	0.10 ± 0.02	37.6 ± 4.0	71.8 ± 4.2	70.3 ± 11.9	10.0 ± 2.1	12.8 ± 0.3	15.9 ± 0.6
11	7.8 ± 0.5	10.3 ± 2.9	0.04 ± 0.01	0.13 ± 0.03	41.6 ± 2.2	72.9 ± 3.8	79.0 ± 17.2	8.0 ± 2.7	13.5 ± 0.5	15.8 ± 0.7
12	7.0 ± 1.0	8.0 ± 2.1	0.07 ± 0.01	0.08 ± 0.02	45.7 ± 6.8	83.3 ± 2.6	46.3 ± 20.2	14.7 ± 1.9	15.9 ± 1.4	17.4 ± 0.2
13	7.5 ± 0.9	7.7 ± 0.7	0.26 ± 0.21	0.08 ± 0.01	24.3 ± 1.8	71.1 ± 4.8	25.0 ± 10.2	3.3 ± 0.3	14.7 ± 0.7	18 ± 0.4
14	16.0 ± 0.8	21.0 ± 6.0	0.09 ± 0.01	0.25 ± 0.04	29.2 ± 1.9	49.4 ± 2.0	36.4 ± 3.1	11.0 ± 0.6	15.3 ± 0.3	16 ± 0.4
15	12.8 ± 1.1	12.0 ± 0.6	0.07 ± 0.01	0.13 ± 0.02	37.1 ± 5.7	63.1 ± 4.1	56.5 ± 20.7	3.3 ± 0.8	16.7 ± 0.4	15.2 ± 0.3
ANOVA										
Environment	NS[z]		***		***		***		***	
Accession	***		*		***		***		***	
Environment x Accession	*		NS		***		***		***	

[w]Values represent mean (± standard errors) of 5 observations for field environment and 3 observations for nursery environment.
[y]Values represent mean (± standard errors) internode extension of 15 observations for field environment and 9 observations for nursery environment.

Table 16. Means of leaf measures by accession for *Sesuvium portulacastrum* when grown in 2.3 L containers in the nursery or planted to the field.

	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)		Stem Diameter (mm)	
Accession	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
1	29.9 ± 0.8[y]	38.3 ± 1.6	8.6 ± 0.2	8.6 ± 0.3	11.7 ± 0.3	8.0 ± 0.5	4.5 ± 0.1	3.9 ± 0.4
2	20.6 ± 1.0	28.2 ± 0.8	7.5 ± 0.4	8.3 ± 0.3	9.6 ± 0.4	7.0 ± 0.5	3.5 ± 0.1	3.6 ± 0.1
3	23.7 ± 0.4	33.8 ± 1.1	8.0 ± 0.4	10.1 ± 0.3	7.6 ± 0.3	6.4 ± 0.5	3.5 ± 0.1	3.7 ± 0.1
4	24.1 ± 0.8	32.9 ± 1.3	7.1 ± 0.2	7.7 ± 0.2	7.9 ± 0.4	4.4 ± 0.2	2.8 ± 0.1	3.6 ± 0.1
5	24.7 ± 0.6	31.3 ± 1.1	6.4 ± 0.4	7.9 ± 0.3	6.2 ± 0.2	4.3 ± 0.3	3.3 ± 0.1	3.6 ± 0.2
6	28.4 ± 1.4	42.9 ± 1.6	11.9 ± 0.5	14.8 ± 0.3	10.4 ± 0.3	10.5 ± 0.4	4.2 ± 0.2	5.3 ± 0.2
7	32.8 ± 0.9	48.9 ± 1.0	15.2 ± 0.4	17.7 ± 0.6	12.8 ± 0.4	10.8 ± 0.3	5.3 ± 0.2	6.0 ± 0.2
8	25.5 ± 0.8	33.1 ± 1.3	6.1 ± 0.2	6.9 ± 0.3	6.7 ± 0.2	4.3 ± 0.2	3.2 ± 0.1	3.9 ± 0.1
9	21.5 ± 0.8	25.0 ± 0.9	6.2 ± 0.2	5.9 ± 0.3	7.9 ± 0.3	5.3 ± 0.2	2.9 ± 0.1	2.9 ± 0.1
10	26.0 ± 0.6	26.3 ± 0.3	5.6 ± 0.5	5.9 ± 0.3	6.4 ± 0.4	3.9 ± 0.2	2.5 ± 0.1	2.6 ± 0.1
11	27.2 ± 0.8	26.6 ± 0.6	6.7 ± 0.3	5.4 ± 0.2	6.1 ± 0.4	3.9 ± 0.4	2.6 ± 0.1	2.7 ± 0.1
12	29.2 ± 1.0	28.2 ± 1.0	6.9 ± 0.3	7.0 ± 0.3	8.1 ± 0.4	5.1 ± 0.4	3.2 ± 0.2	3.3 ± 0.1
13	20.7 ± 1.2	29.2 ± 0.6	5.3 ± 0.3	5.7 ± 0.2	7.3 ± 0.5	5.8 ± 0.2	2.5 ± 0.1	2.8 ± 0.1
14	26.0 ± 1.0	31.9 ± 0.9	7.4 ± 0.3	6.8 ± 0.3	8.5 ± 0.2	4.4 ± 0.3	3.7 ± 0.1	3.2 ± 0.1
15	33.7 ± 7.4	29.8 ± 0.6	6.5 ± 0.4	5.2 ± 0.2	8.8 ± 0.6	5.1 ± 0.3	3.0 ± 0.1	3.0 ± 0.1
ANOVA								
Environment	***[z]		***		***		***	
Accession	***		***		***		***	
Environment x Accession	***		***		***		***	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 17. Maximum, minimum, mean, standard deviation, coefficient of variation of growth measures combined for all accessions of *Sesuvium portulacastrum* across all environments.

	Max	Min	Mean	Standard Deviation	CV[x]
Plant height (cm)	29.0	3.0	11.5[y]	5.3	45.8
Flower count	303.0	0.0	33.3	47.5	142.6
Height/width ratio ($cm \cdot cm^{-1}$)	0.89	0.2	0.11	0.1	88.6
Ornamental rating	5	1	3.0	0.7	24.7
Growth index (cm^{3})	785672.0	864.0	199752.0	180270.1	90.2
Internode length (mm)	126.0	8.6	48.7[z]	25.1	51.6
Flower diameter (mm)	23.0	10.9	16.4	2.4	13.7
Pedicle length (mm)	113.0	1.0	8.6	8.3	96.8
Lamina length (mm)	92.1	15.3	28.7	7.4	25.7
Lamina width (mm)	20.0	2.8	8.0	3.1	39.4
Petiole length (mm)	16.2	2.0	7.4	2.7	36.2

[x]Coefficient of variation.
[y]Means combined across all accessions and environments, N=111.
[z]Means combined across all accession and environments N=322 for internode mean and N=230 for floral data.

Table 18. Means of growth measures separated by origin of accession along Texas coast for *Sesuvium portulacastrum* when grown in 2.3 L containers in the nursery or planted to the field.

	Height (cm)	Flower count (No./plant)		Height:width ratio ($cm \cdot cm^{-1}$)		Internode length (mm)		Flower diameter (mm)	
Location	Combined[u]	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
South	13.5 ± 1.0	58.74 ± 17.21	6.6 ± 2.37	0.1 ± 0.01[v]	0.19 ± 0.02	33.57 ± 1.7[x]	74.8 ± 4.53	17.15 ± 0.46[y]	17.17 ± 0.35
Central	12.6 ± 0.8	36.63 ± 5.28	6.33 ± 1.01	0.08 ± 0.01	0.14 ± 0.02	31.5 ± 1.54	66 ± 2.46	16.19 ± 0.26	16.79 ± 0.34
North	8.0 ± 0.4	58.84 ± 8.51	10.53 ± 1.17	0.09 ± 0.04	0.1 ± 0.01	35.48 ± 1.83	70.62 ± 2.22	14.17 ± 0.36	16.42 ± 0.27
ANOVA									
Environment	NS[z]	***		***		***		***	
Location	***	NS		NS		NS		***	
Environment x Location	NS	NS		NS		NS		***	

[u]Environments combined when not significant to $P \leq 0.05$. Values represent means (± standard errors) of 38, 39, and 34 observation for south, central, and northern coasts, respectively.

[v]Values represent means (± standard errors) of height: width ratio of 23, 24, and 19 observations for south, central, and northern coasts, respectively for field environment and of 15, 15, and 15 observations for south, central, and northern coasts, respectively for nursery environment.

[x]Values represent means (± standard errors) of internode extension for 69, 69, and 51 observations for south, central, and northern coasts, respectively for field environment and of 44, 45, and 45 observations for south, central, and northern coasts, respectively for nursery environment.

[y]Values represent means (± standard errors) of flower diameter for 34, 51, and 29 observations for south, central, and northern coasts, respectively for field environment and of 29, 42, and 45 observations for south, central, and northern coasts, respectively for nursery environment.

[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively

Table 19. Means of leaf measures separated by origin of *S. portulacastrum* accession along Texas coast when grown in 2.3 L containers in the nursery or planted to the field.

Location	Lamina length (mm)		Lamina width (mm)		Petiole length (mm)		Stem diameter (mm)	
	Field	Nursery	Field	Nursery	Field	Nursery	Field	Nursery
South	27.93 ± 0.55[y]	38.86 ± 1.15	9.65 ± 0.43	11.39 ± 0.65	9.72 ± 0.34	7.53 ± 0.46	4.00 ± 0.13	4.52 ± 0.18
Central	25.23 ± 1.08	31.36 ± 0.52	7.17 ± 0.16	7.47 ± 0.27	8.19 ± 0.2	5.47 ± 0.23	3.43 ± 0.06	3.48 ± 0.06
North	25.09 ± 0.56	27.07 ± 0.39	6.14 ± 0.18	5.98 ± 0.14	6.91 ± 0.21	4.80 ± 0.16	2.70 ± 0.06	2.85 ± 0.05
ANOVA								
Environment	***[z]		*		***		***	
Location	***		***		***		***	
Environment x Location	***		*		NS		NS	

[y]Values represent mean (± standard errors) of 15 observations for field environment and 9 observations for nursery environment.
[z] NS,*,**,***Non significant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Cluster analysis identified one group that was formed by three of the five southern accessions, and a second group with all other accessions (Fig. 5). The three accessions forming their own group had larger leaves, stems, and were taller than the other accessions.

The accessions from the southern collection had larger leaves, thicker stems, and a more upright habit than collections from either the central or northern coast. Leaf morphology was plastic in response to environment for most accessions of *S. portulacastrum*. Flowering seemed more dependent on the environment than region of collection, so a region cannot be targeted for future collection areas.

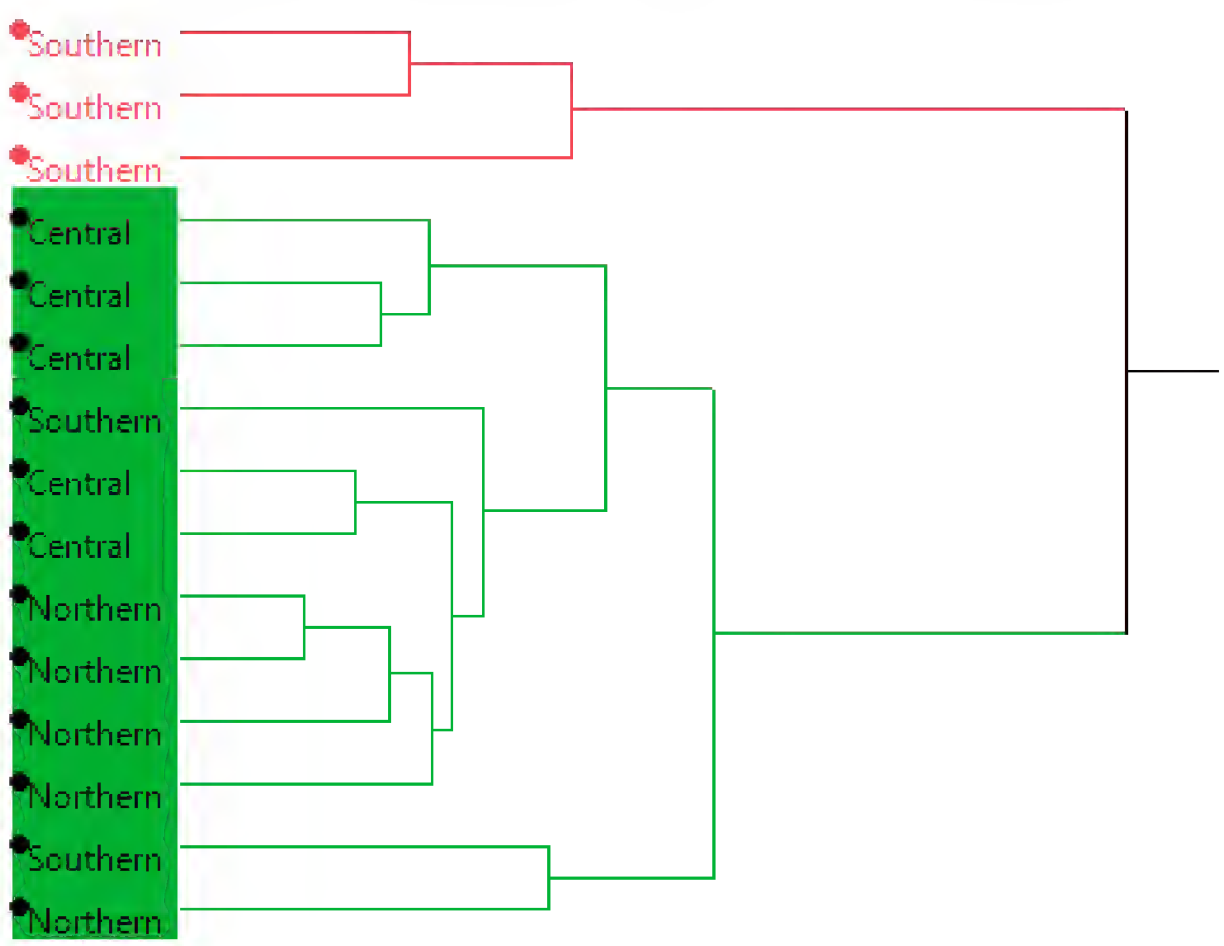

Fig. 5. Hierarchical Cluster analysis using Wards distance of *S. portulacastrum* accessions based on morphological traits. Different colors indicate different cluster groups and labels indicate accessions collection region.

CONCLUSIONS

We found differences in potential commercially important vegetative and floral traits among accessions for all four of the species tested and regional differences in traits of interests in *B. frutescens* and *O. drummondii*. This information could be used to guide the collection of future genotypes of *B. frutescens* and *O. drummondii*. This will assist future collectors of germplasm to target their collection efforts to regions based on the characteristics of material in which they are interested. Further collection of *E. procumbens* needs to be performed to test for differences in northern regional populations.

In the future, studies need to be performed to calculate heritability and stability of these characteristics in more environments to determine if these traits can be used for selection to make gains in ornamental performance over a broader range of environments.

ACKNOWLEDGEMENTS

This study was included as part of a dissertation written in partial fulfillment of the requirements for the Ph.D. degree by Sean Carver. This work was supported in part by funds from Texas A&M AgriLife Research through Hatch Funds from the National Institute of Food and Agriculture. Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the authors, Texas A&M University, or Texas A&M AgriLife Research and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

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APPENDICES

Appendix 1. GPS coordinates and location description of collection site for each accession of *Oenothera drummondii*.

Accession	Latitude	Longitude	Description of location	Regional location along Texas coast
1	26° 06.879	97° 09.965	Gulf and Gardenia on Gulf Beach South Padre Island, TX	South
2	27° 38.623	97° 11.288	Hwy 361 and Gulf Access Rd. 3 Top of Dune	Central
3	26° 06.070	97° 09.864	Gulf and E. Martin Gulf Beach South Padre Island, TX	South
4	26° 07.472	97° 10.039	Gulf and Georgia Ruth Gulf Beach South Padre Island, TX	South
5	26° 14.445	97° 11.120	Where Park Rd 100 ends north of South Padre Island, TX	South
6	26° 11.814	97° 10.643	Park Rd 100 North of South Padre Island, Tx	South
7	28° 35.886	95° 58.718	Beach in Matagorda Beach TX	Central
8	28° 36.291	95° 57.588	Beach in Matagorda Beach TX	Central
9	28° 57.043	95° 17.588	Surfside Beach	North
10	29° 06.698	95° 04.956	Beach Access 2 Jamaica Beach	North
11	29° 40.203	94° 03.950	Side of Rd Near end of Hwy 87 Mcfaddin NWR	North
12	29° 12.519	94° 55.596	Galveston 3005 Rd Beach Access 14 in Dunes	North
13	29° 33.076	94° 23.333	Hwy 87 and 124	North
14	29° 26.297	94° 39.666	Off of HWY 87 on Gulf View on Crystal Beach	North
15	27° 51.816	97° 20.057	Sunset Park Portland Texas growing in oyster shell	Central
16	28° 5.1027	97° 20.057	Fulton Beach Rd in front of Royal Oaks Subdivision	?Central

[z]Latitude and Longitude presented in degrees and decimal minutes format

Appendix 2. GPS coordinates and location description of collection site for each accession of *Borrichia frutescens*.

Accession	Latitude	Longitude	Description of location	Regional location along Texas coast
1	27° 42.341	97° 09.224	Hwy 361 and Gulf Access Rd. 2	central
2	27° 38.867	97° 11.587	Hwy 361 and Gulf Access Rd. 3	central
3	26° 06.742	97° 10.212	Laguna St. and Campeche	southern
4	27° 17.363	97° 39.710	End of Rd. 771 in Rivera Beach	southern
5	26° 06.068	97° 09.864	Gulf and E. Martin South Padre Island, TX	southern
6	26° 08.435	97° 10.492	Convention Center in South Padre Island, TX	southern
7	26° 04.353	97° 22.510	Port Isabel Texas next to Whataburger	southern
8	26° 04.715	97° 12.712	Shore Dr. Port Isabel, TX	southern
9	26° 33.535	97° 25.568	Mansfield and North Shore Port Mansfield, TX	southern
10	26° 07.175	97° 09.945	Gulf and E. Mars South Padre Island, TX	southern
11	27° 38.647	97° 17.057	Laguna Shores Rd. Flour Bluff	central
12	26° 34.163	97° 25.774	Fred Stone Park Port Mansfield, TX	southern
13	28° 41.805	95° 57.570	Matagorda Beach along main road	central
14	28° 39.614	96° 24.754	End of 172 Rd in Port Alto, TX	central
15	28° 23.470	96° 50.245	Town Park in Austwell, TX	central
16	28° 33.601	96° 32.247	Public Beach in Magnolia Beach, TX	central
17	28° 27.159	96° 24.326	Park in Port O'Connor, TX	central
18	28° 24.581	96° 43.542	Park living in effluent stream, Sea Drift, TX	central
19	28° 02.160	97° 02.520	Beginning of Fulton Beach Rd. Rockport TX	central
20	28° 57.017	95° 17.142	End of RD332 Surfside	northern
21	29° 22.040	94° 45.607	Hwy 87 Side of RD Bolivar	northern
22	29° 40.091	94° 04.279	McFaddin NWR on Beach	northern
23	29° 42.612	93° 51.539	1st St. in Sabine TX	northern
24	29° 22.042	94° 45.606	Hwy 87 Side on side of RD Bolivar	northern
26	29° 33.079	95° 22.336	On Bay Beach Park View and Port Velasco	northern
27	29° 12.522	94° 55.598	124 @ Hwy 87 High Island in Ditch	northern
28	29° 08.671	97° 03.506	3005 Rd Beach Access 14 Beach in Galveston	northern

[z]Latitude and Longitude presented in degrees and decimal minutes format

Appendix 2. GPS coordinates and location description of collection site for each accession of *Erigeron procumbens*.

Accession	Latitude	Longitude	Description of location	Regional location along Texas coast
1	27° 48.886[z]	97° 04.355	2016 11TH St. Port Aransas, TX	Central
2	27° 42.343	97° 09.240	Hwy 361 and Gulf Access Rd. 2	Central
3	27° 53.658	97° 18.440	Walmart Parking lot Portland, TX	Central
4	27° 40.141	97° 17.239	Wells Fargo Parking lot Flour Bluff, TX	Central
5	26° 07.093	97° 10.165	Park Rd 100 and Mars St. South Padre Island, TX	Southern
6	27° 54.524	97° 08.947	Central Park Aransas Pass, TX	Central
7	27° 08.072	97° 47.561	Hwy 77 Kennedy County Rest Stop	Southern
8	26° 07.185	97° 10.256	Laguna and Constellation South Padre Island, TX	Southern
9	26° 07.598	97° 10.069	Gulf and Cora Lee South Padre Island, TX	Southern
10	26° 30.713	97° 27.841	Hwy 186 in Ditch with Sand	Southern
11	26° 06.738	97° 10.210	Laguna and Mars South Padre Island, Texas	Southern
12	27° 37.411	97° 13.468	14175 Jack Fish Ave. The Island Corpus Christi, TX	Central
13	27° 48.341	97° 04.823	11th St. and Gulf Access Rd 1A Port A, TX	Central
14	27° 38.808	97° 16.958	Laguna Shores Rd. Flour Bluff, TX	Central
15	27° 38.877	97° 11.582	Hwy 361 and Gulf Access Rd. 3	Central
16	28° 27.154	96° 24.327	Water front park in Port O'Connor, TX	Central
17	28° 08.317	96° 58.153	4th St growing in ditch, Lamar, TX	Central
18	29° 05.631	95° 06.601	Just north of Toll Bridge on County RD 3005	Northern

[z]Latitude and Longitude presented in degrees and decimal minutes format

Appendix 3. GPS coordinates and location description of collection site for each accession of *Sesuvium portulacastrum*.

Accession	Latitude	Longitude	Description of location	Regional location along Texas coast
1	26° 34.164[z]	97° 25.745	Fred Stone Park Port Mansfield	Southern
2	27° 48.201	97° 4.654	Hwy 361 and Gulf Access Rd 1A	Central
3	27° 17.363	97° 39.71	End of Rd 771 in Rivera Beach	Central
4	26° 4.715	97° 12.714	Shore Dr. Port Isabel, TX	Southern
5	26° 4.354	97° 12.718	Port Isabel, TX	Southern
6	26° 4.716	97° 12.715	Port Isabel, TX	Southern
7	26° 7.47	97° 10.042	Gulf Beach South Padre Island, TX	Southern
8	28° 27.163	96° 24.325	Park in Port O'Connor, TX	Central
9	29° 6.698	95° 4.956	Beach Access Rd 2 Jamaica Beach	Northern
10	29° 40.09	94° 4.279	McFaddin NWR	Northern
11	29° 33.076	94° 23.338	124 @ HWY87 High Island	Northern
12	28° 57.02	95° 17.148	End of Rd 332 Surfside Beach	Northern
13	29° 12.523	95° 55.598	Beach Access 14 in dunes Galveston	Northern
14	27° 51.719	97° 20.446	Sunset Park Portland Texas	Central
15	28° 8.671	97° 3.506	Fulton Beach Rd	Central

[z]Latitude and Longitude presented in degrees and decimal minutes format